Chapter 1

Photo courtesy of the Georgia Department of Natural Resources

Design of the Wadeable Streams Assessment

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Why Focus on Wadeable Streams?

Like the network of blood vessels that supply life-giving oxygen and nutrients to all parts of the human body, streams and rivers form a network that carries essential water to all parts of the nation. The human body has far more small capillaries than large, major arteries and veins; similarly, only a few U.S. rivers span large portions of the country (e.g., the Mississippi, Missouri, or Columbia rivers). Most of the nation's waterways are much smaller stream and river systems that form an intimate linkage between land and water.

The WSA addresses these smaller systems, which ecologists often refer to as "wadeable" because they are small and shallow enough to adequately sample without a boat. Almost every state, university, federal agency, and volunteer group involved in water quality monitoring has experience sampling these smaller flowing waters; therefore, a wide range of expertise was available for the WSA's nationwide monitoring effort.

About 90% of perennial stream and river miles in the United States are small, wadeable streams. Stream and river ecologists commonly use the term Strahler stream order to refer to stream size, and wadeable streams generally fall into the 1st- through 5th-order range (Figure 1). First-order streams are the headwaters of a river, where the life of a river begins; as streams join one another, their stream order increases. It is important to note that many 1st-order streams, particularly those located in the western United States, do not flow continuously. These intermittent or ephemeral streams were not included in the WSA because well-developed indicators to assess these waterbodies do not yet exist. At the other end of the range are larger-order rivers and streams that

Sawmill Creek, MA, in the Northern Appalachians ecoregion
(Photo courtesy of Colin Hill, Tetra Tech, Inc.).

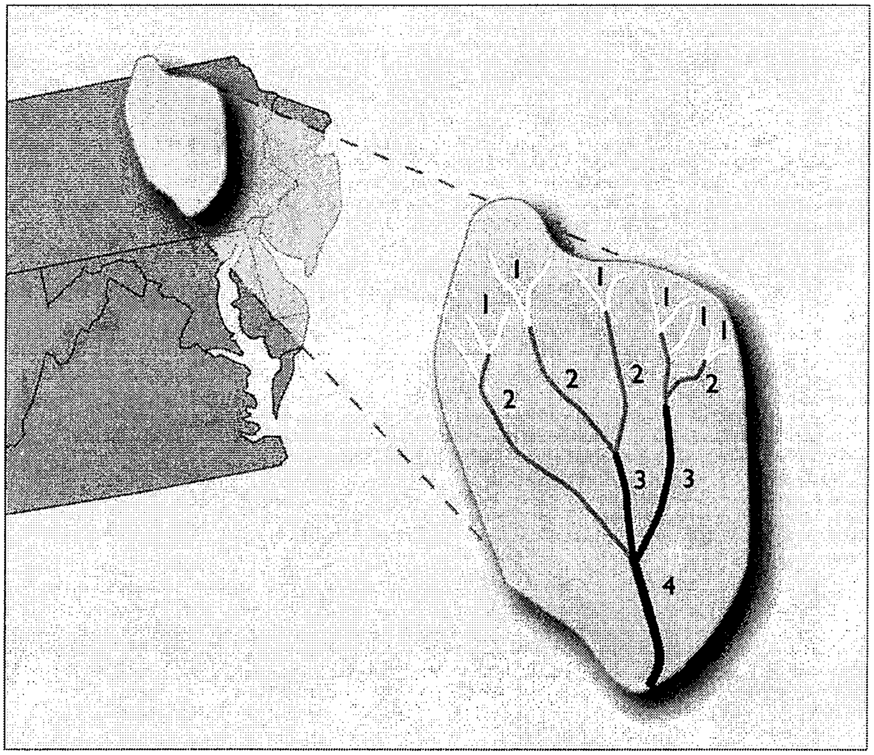


Figure 1. Strahler stream order diagram (U.S. EPA/WSA). Stream size is categorized by Strahler stream order, demonstrated here for a watershed. The confluence (joining) of two 1st-order streams forms a 2nd-order stream; the confluence of two 2nd-order streams forms a 3rd-order stream.

are too deep for wadeable sampling methods. These deeper waterbodies will be included in a future survey of non-wadeable rivers.

Stream order (stream size) affects a stream's natural characteristics, including the biological communities that live in the stream, such as fish and invertebrates. Very small 1st-order and 2nd-order streams are often quite clear and narrow and are frequently shaded by grasses, shrubs, and trees that grow along the stream bank (Figure 2). The food base of these streams is found along the stream bank and tends to consist of leaves and terrestrial insects, which dominate the streams' ecology, along with algae that attach to rocks and wood, aquatic insects adapted to shredding leaves and scraping algae, and small fish that feed on these organisms. In contrast, larger 6th- and 7th-order rivers typically appear muddy because their flow carries accumulated sediments downstream. These rivers are wide enough that the canopy cover along their banks shades only a narrow margin of water along the river's edge. The food base for these waterbodies shifts towards in-stream sources, such as algae; downstream drift of small organisms; and deposition of fine detritus. Although the aquatic communities of larger rivers include the algae and terrestrial insects found in streams, these rivers are dominated by insects adapted to filtering and gathering fine organic particles, and larger fish that are omnivorous (feeding on plants and animals) and/or piscivorous (feeding on smaller fish).

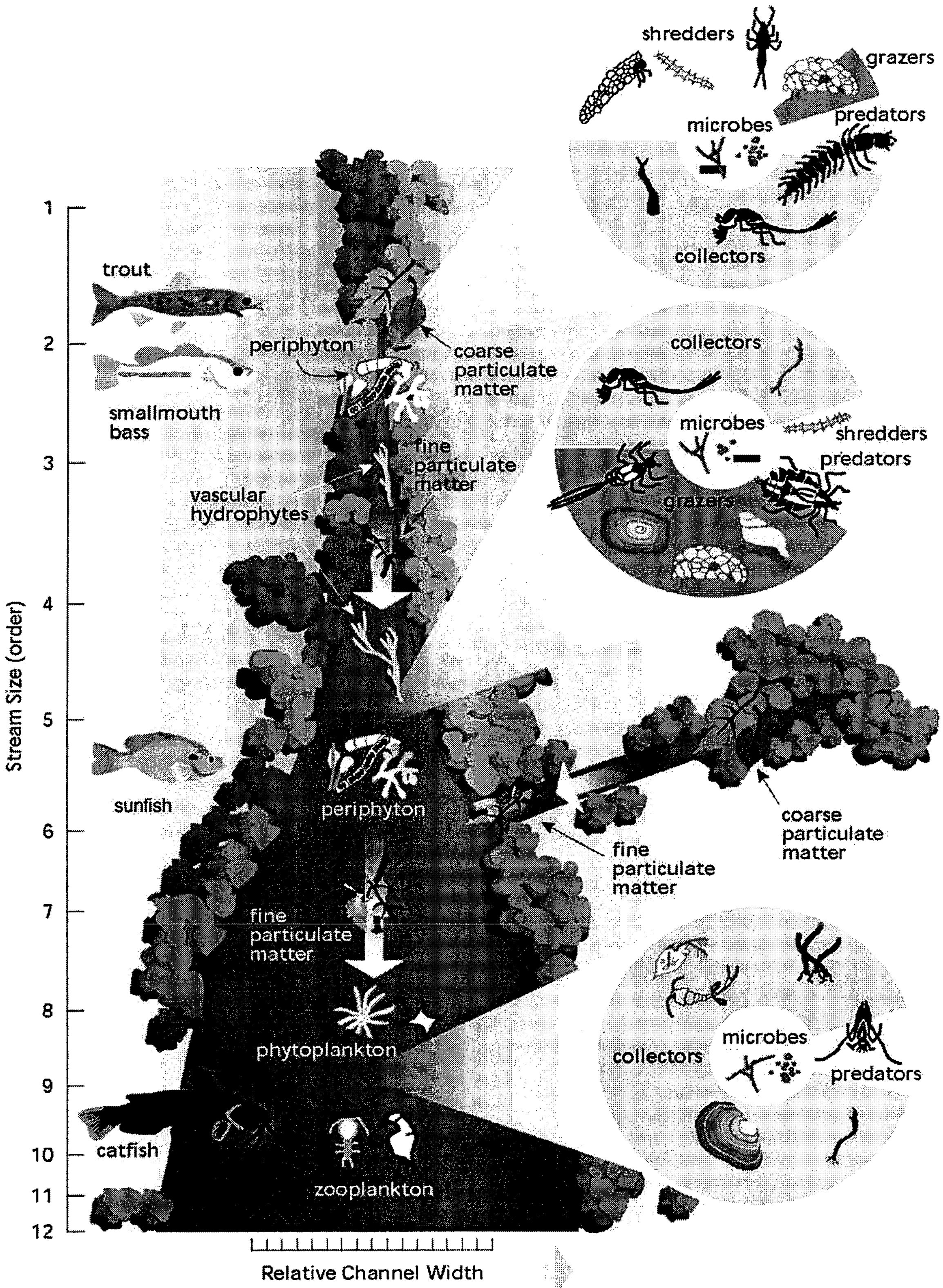


Figure 2. Stream characteristics change as the stream's size or stream order increases (Vannote et al., 1980).

What Area Does the WSA Cover?

This WSA encompasses the wadeable streams of the conterminous United States, or lower 48 states (Figure 3). This land area covers 3,007,436 square miles (mi^2) and includes private, state, tribal, and federal land. Although not included in this report, initial stream-sampling projects outside the conterminous United States have begun and will be included in future assessments. For example, scientists in Alaska sampled streams in the Tanana River Basin (a subbasin to the Yukon River) during 2004 and 2005, and they expect to report their results in 2007; Guam has begun implementation of a stream survey; and Puerto Rico is developing indicators for assessing the condition of its tropical streams. In addition, the State of Hawaii began stream sampling using WSA techniques on the island of Oahu in 2006.

State boundaries offer few insights into the true nature of features that mold our streams and rivers. The most fundamental trait that defines U.S. waters is annual precipitation (Figure 4). A sharp change occurs on either side of the

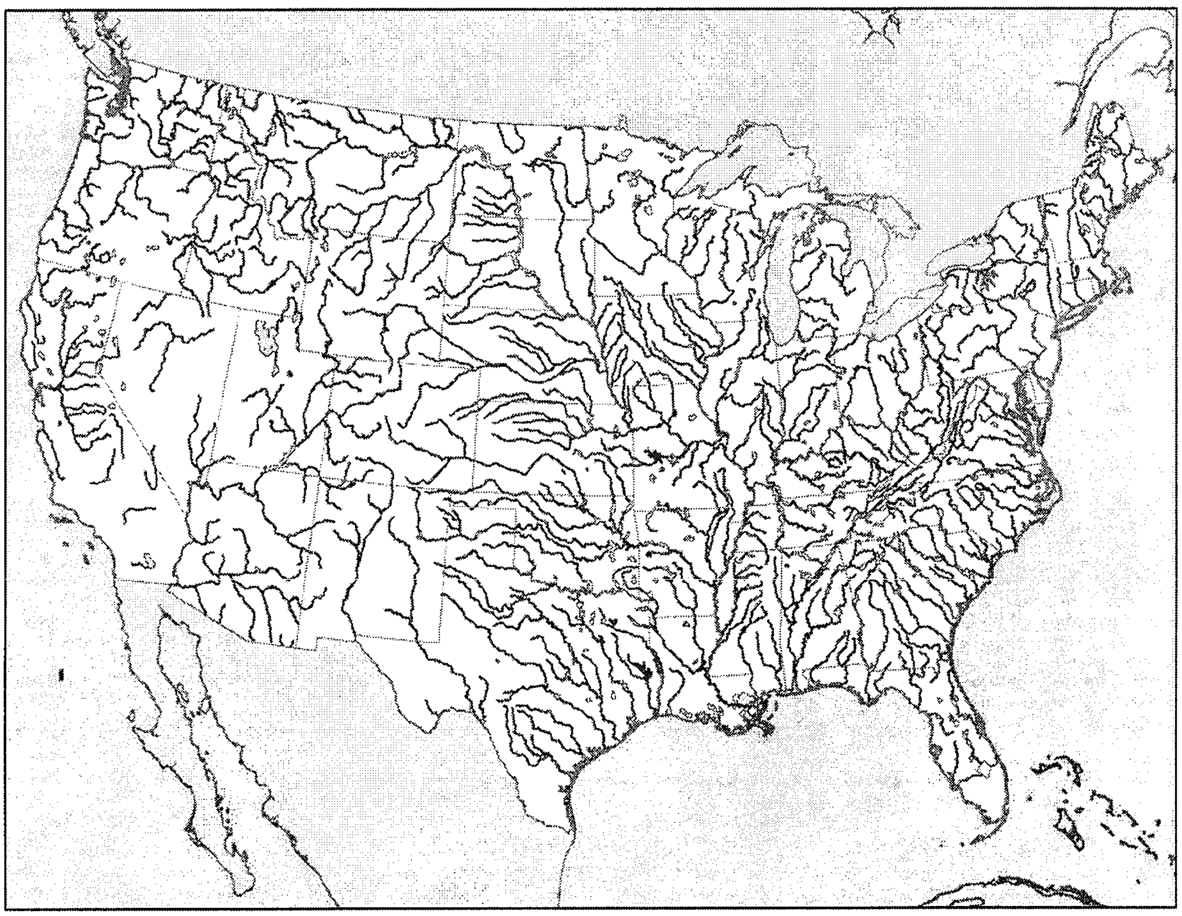


Figure 3. Major rivers and streams of the conterminous United States (NationalAtlas.gov, 2006). Major rivers comprise only 10% of the length of U.S. flowing waters, whereas the nation's wadeable streams and rivers comprise 90% of the length of U.S. flowing waters.

100th longitude that runs from west Texas through North Dakota, with precipitation falling plentifully to the east, but sparsely to the west. (The high mountains of the western United States and the Pacific coast are exceptions to the general scarcity of water in the West.) The east-west divide in moisture has not only shaped the character of the nation's waters, but also how they are used, valued, and the even the legal systems with which they are managed. A second divide that defines the nature of U.S. rivers and streams is the north-south gradient in temperature.

Young Womans Creek, PA, in the Southern Appalachians ecoregion (Photo courtesy of the Great Lakes Environmental Center).

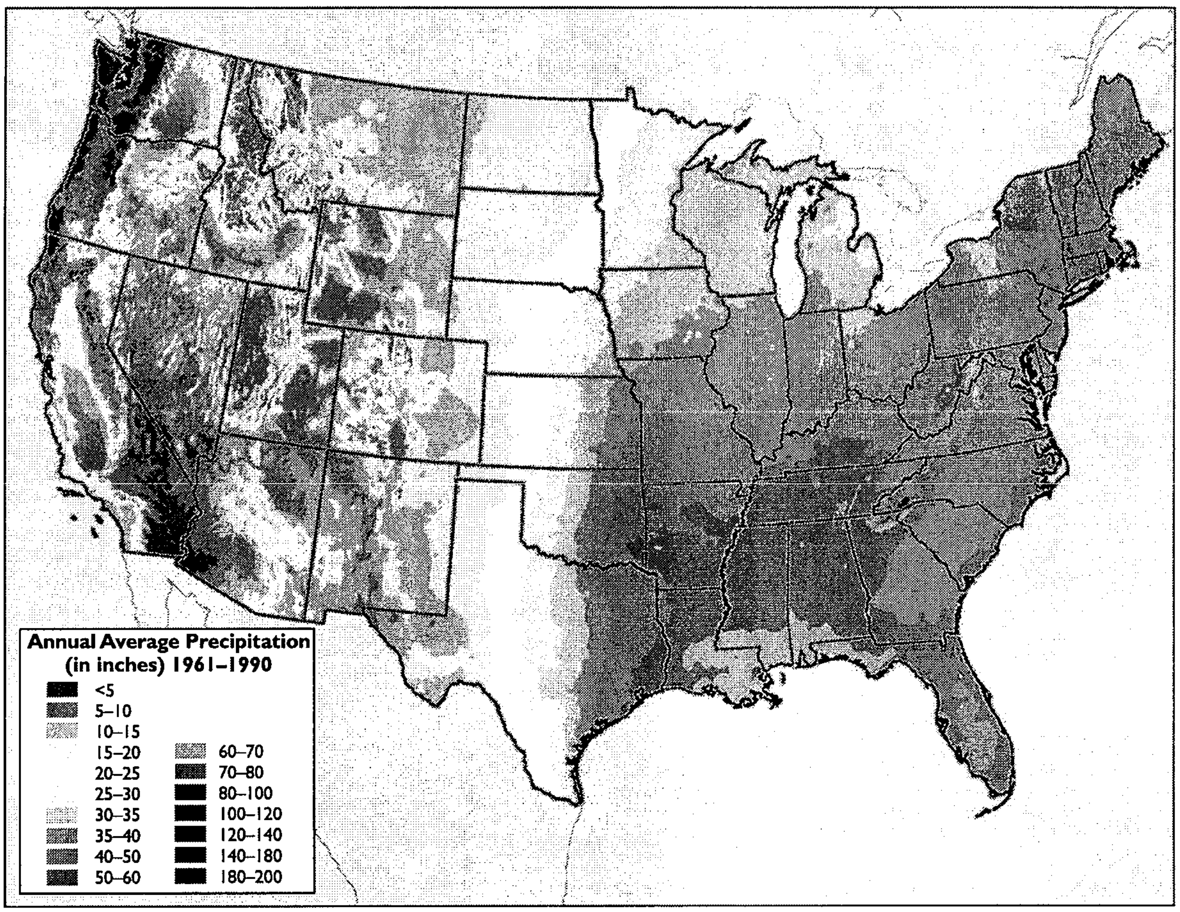


Figure 4. Average annual precipitation of the United States, 1961–1990 (NOAA, National Climatic Data Center). The 100th longitude meridian runs from Texas north through North Dakota and reveals a major gradient of precipitation that defines differences in western and eastern streams.

The nation includes a wide diversity of landscapes, from the varied forests of the East, to the immense agricultural plains and grasslands of the Midwest, to the deserts and shrublands of the Southwest, to the giant mountain ranges of the West (Figure 5). In the eastern part of the country, the Appalachian mountains run from Maine to Alabama, crossing climatic boundaries and separating the waters flowing to the Atlantic Ocean from those flowing to the Gulf of Mexico. The larger mountain ranges in the West link their landscapes together: the Rockies through the heart of the West; the Cascades, which crown the Northwest in snow; the Sierra Nevada in California; and the Coastal Range, which plummets to the Pacific Ocean, with a fault-block shoreline that stretches from the Santa Monica mountains to Kodiak Island. The Coastal Plains of the East and Southeast and the Great Plains of the interior provide other major landform features that mark the country.

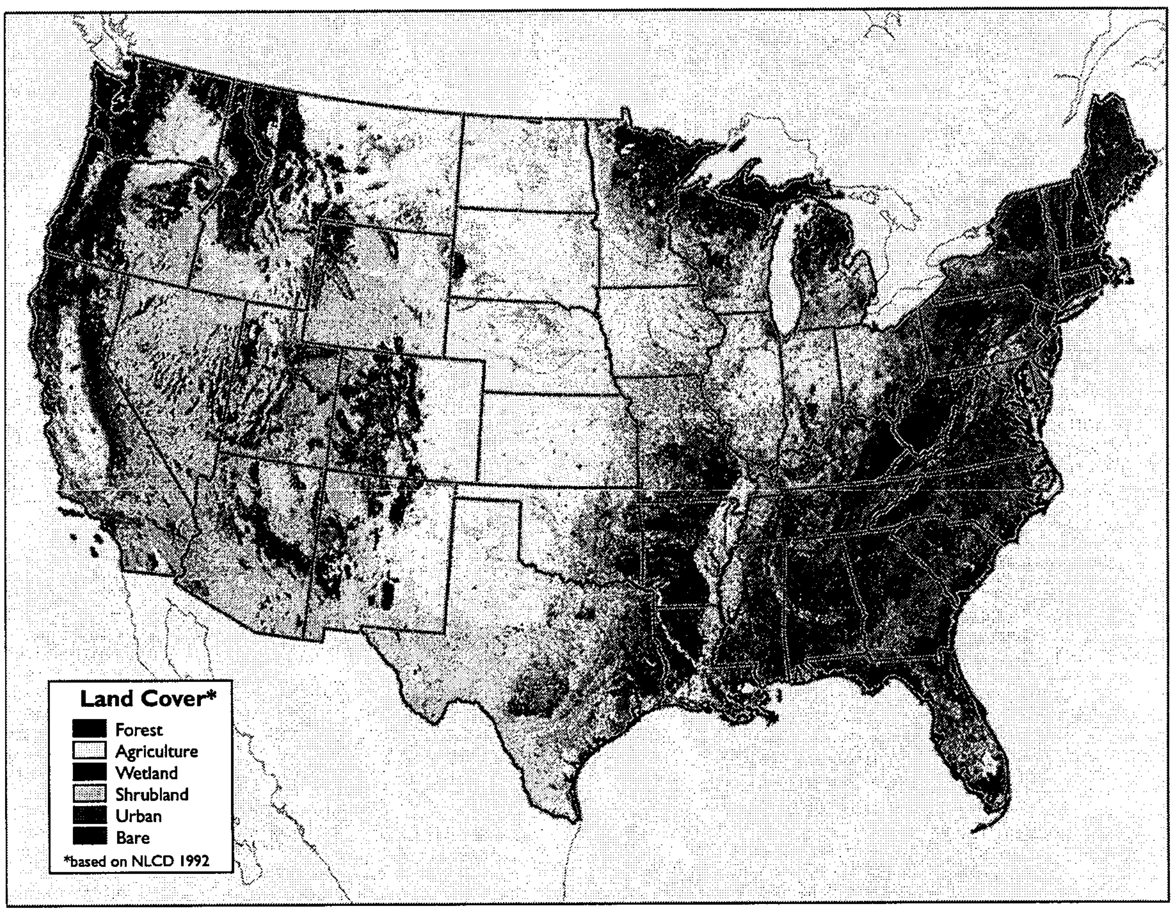


Figure 5. Major land cover patterns of the conterminous United States (USGS, 2000).

The establishment and spread of European colonies and the Industrial Revolution intensified the transformation of the nation's natural landscape, as greater numbers of people arrived and modified many of the features of the land and waters. As the nation's population grew and cities and towns were established, tens of thousands of dams were constructed to alter the flow of virtually every major river in the United States.

Historically, people have tended to live where water is more abundant. Current population patterns based on 2000 U.S. Census Bureau data reflect the historical abundance of waters in the East and forecast the growing challenges facing the water-scarce regions in the West, where population has grown in recent years (Figure 6). The current and future condition of the nation's waters will continue to be influenced by population patterns, as well as how the components of a watershed, including surface water, groundwater, and the land itself, are used.

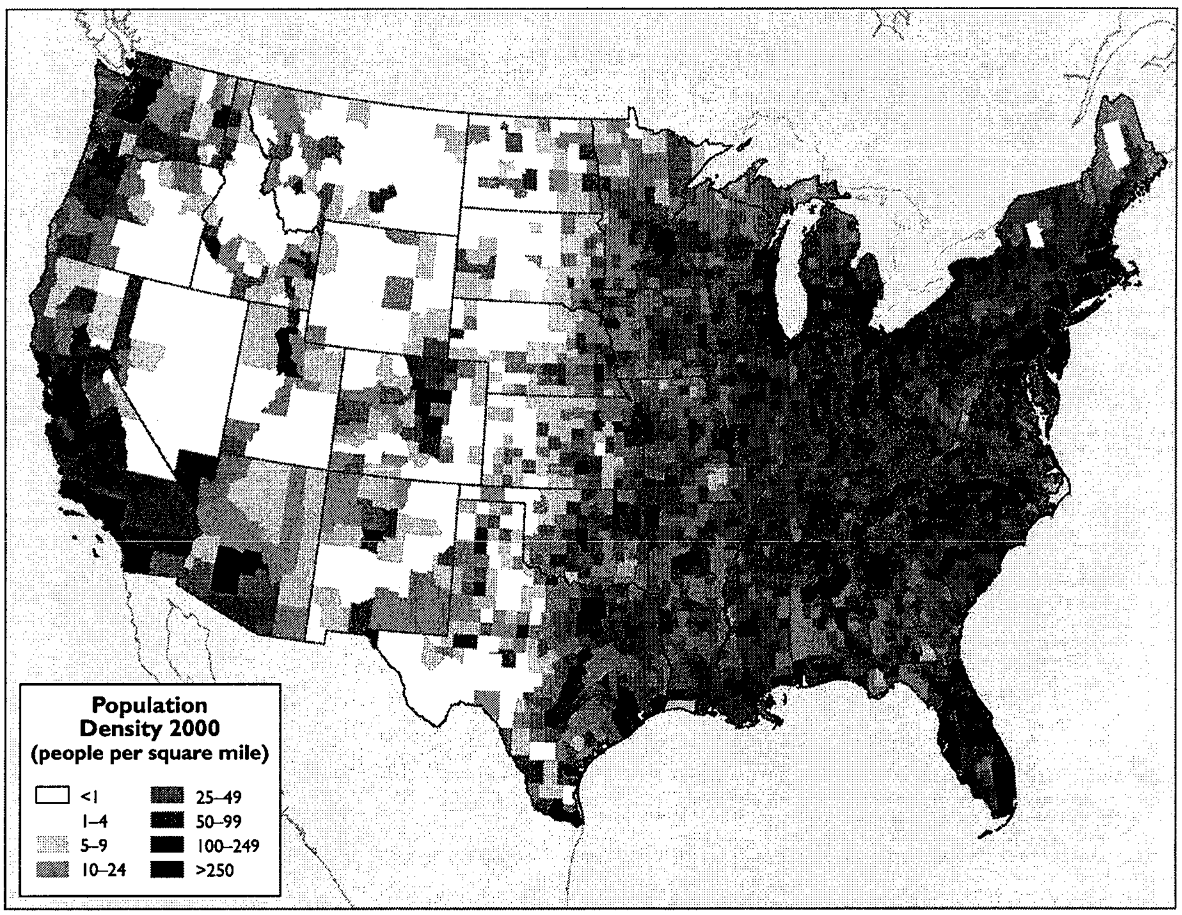


Figure 6. Human population density (people per square mile) based on 2000 U.S. Census Bureau data (ESRI, 2005).

What Areas Are Used to Report WSA Results?

The conterminous United States is the broadest-scale unit for which WSA results are reported. For this report, this area has been split into three major regions—the Eastern Highlands, the Plains and Lowlands, and the West. These three regions correspond to major climate and landform patterns across the United States (Figure 7).

The Eastern Highlands region is composed of the mountainous areas east of the Mississippi River and includes the piedmont to the east of the Appalachians and the interior plateau to their west. The Plains and Lowlands region encompasses the Atlantic and Gulf of Mexico coastal plains and the lowlands of the Mississippi Delta, as well as the portions of the Midwest from the Dakotas down through most of Texas. The West region includes the western portion of the country, from the desert southwestern United States and the Rocky Mountains to the Pacific Ocean. Chapter 2 of this report describes the WSA results for these three major regions.

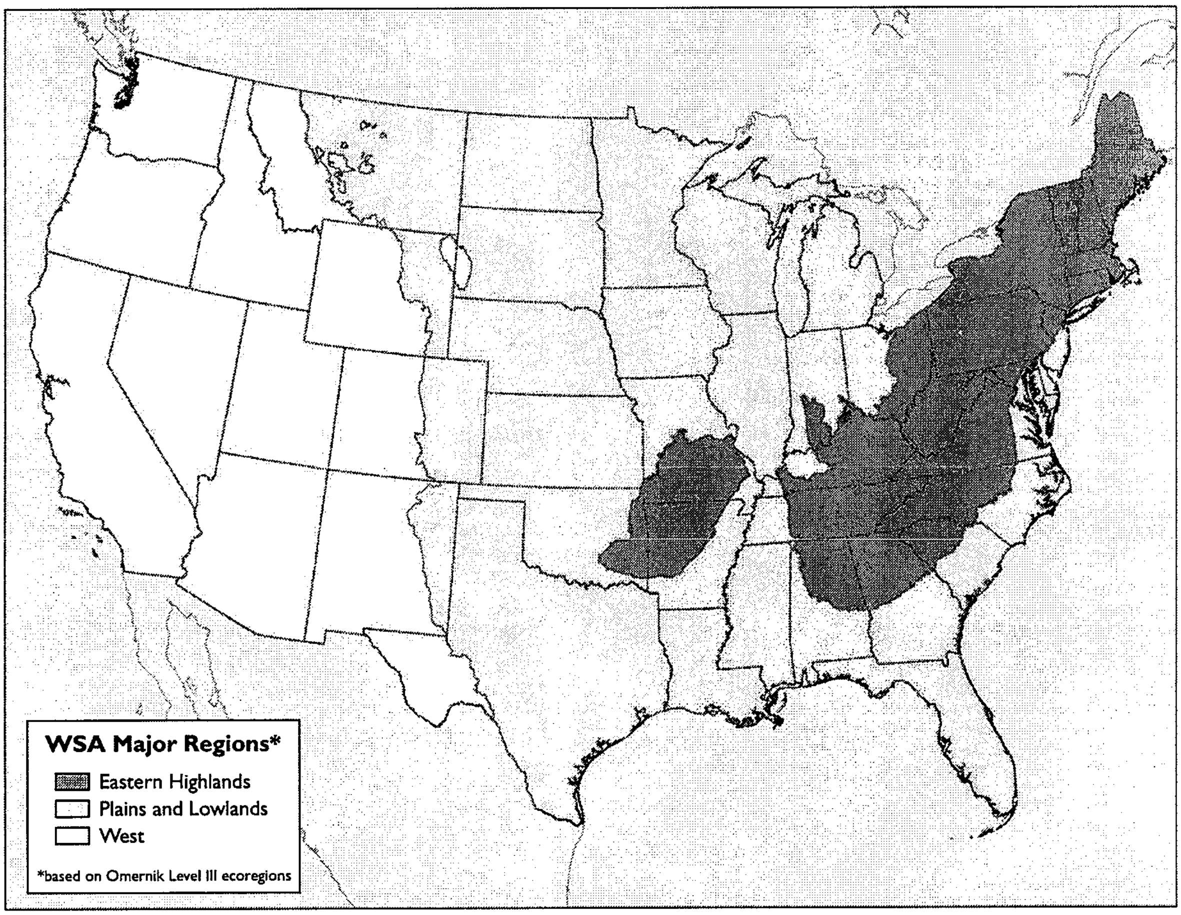


Figure 7. Three major regions were surveyed for the WSA (U.S. EPA/WSA).

A finer-scale reporting unit included in the WSA consists of nine ecological regions (ecoregions) (Figure 8) that further divide the three major regions. The three major regions and the nine ecoregions outlined in this report are aggregations of smaller ecoregions defined by EPA. Areas are included in an ecoregion based on similar landform and climate characteristics. For example, water resources within a particular ecoregion have similar natural characteristics and respond similarly to natural and anthropogenic stressors. Typically, management practices aimed at preventing degradation or restoring water quality apply to many flowing waters with similar problems throughout an ecoregion. This report presents results by ecoregions because the patterns of response to stress, and the stressors themselves, are often best understood in a regional context. The results for the nine ecoregions are reviewed in Chapter 3 of this report.

The Eastern Highlands region is divided into two ecoregions: the Northern Appalachians ecoregion, which encompasses New England, New York, and northern Pennsylvania, and the Southern Appalachians ecoregion, which extends from Pennsylvania into Alabama, through the eastern portion of the Ohio Valley, and includes the Ozark Mountains of Missouri, Arkansas, and Oklahoma.

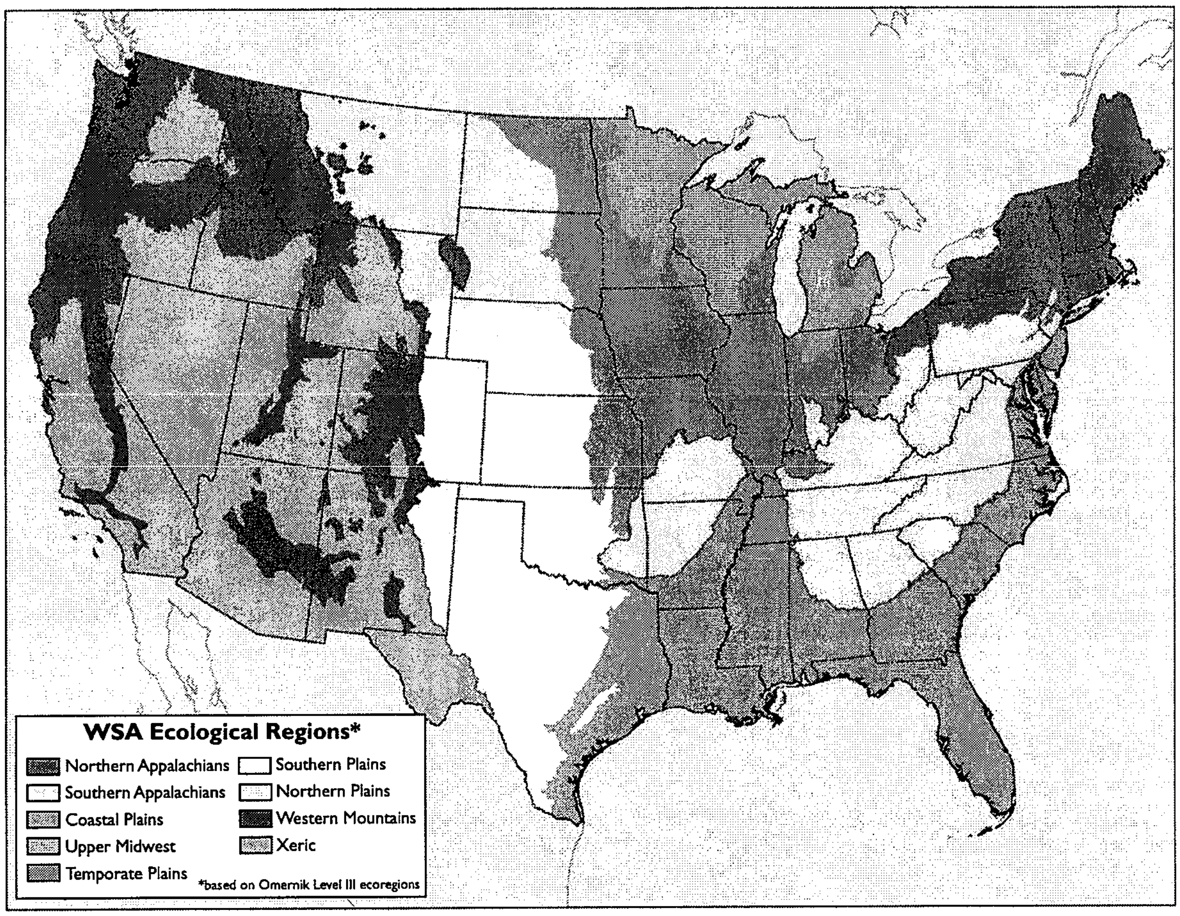


Figure 8. Nine ecoregions were surveyed for the WSA (U.S. EPA/WSA).

The Plains and Lowlands region includes five WSA ecoregions: the Coastal Plains, the Upper Midwest, the Temperate Plains, the Northern Plains, and the Southern Plains. The Coastal Plains ecoregion covers the low-elevation areas of the East and Southeast, including the Atlantic and Gulf of Mexico coastal plains and the lowlands of the Mississippi Delta, which extend from the Gulf of Mexico northward through Memphis, TN. The Upper Midwest ecoregion is dominated by lakes and has little elevation gradient. The Temperate Plains ecoregion in the midwestern United States is probably most well-known as the Cornbelt. The Northern Plains and Southern Plains ecoregions are better known as the Great Prairies, with the Northern Plains ecoregion encompassing North Dakota, South Dakota, Montana, and northeast Wyoming, and the Southern Plains ecoregion encompassing parts of Nebraska, Kansas, Colorado, New Mexico, Oklahoma, and Texas.

The West region includes two WSA ecoregions: the Western Mountains ecoregion and the arid or Xeric ecoregion. The Western Mountains ecoregion includes the Cascade, Sierra Nevada, and Pacific Coast mountain ranges in the coastal states; the Gila Mountains in the southwestern states; and the Bitteroot and Rocky Mountains in the northern and central mountain states. The Xeric ecoregion includes both the true deserts and the arid lands of the Great Basin.

Some states participating in the WSA assessed an even finer state-scale resolution than the ecoregion scale by sampling additional random sites within their state borders. Although these data are included in the analysis described in this report, state-scale results are not presented for each state. These states are preparing similar analyses that reflect their respective water quality standards and regulations.

How Were Sampling Sites Chosen?

The WSA sampling locations were selected using modern survey design approaches. Sample surveys have been used in a variety of fields (e.g., election polls, monthly labor estimates, forest inventory analyses, National Wetlands Inventory) to determine the status of populations or resources of interest using a representative sample of a relatively few members or sites. This approach is especially cost effective if the population is so large that all components cannot be sampled or if obtaining a complete census of the resource is unnecessary to reach the desired level of precision for describing conditions.

Survey data are frequently reported in the news. For example, the percentage of children 1–5 years old living in the United States who have high lead levels in their blood is 2.2% +/- 1.2%, an estimate based on a random sample of children in the United States. The WSA results have similar rigor in their ability to estimate the percentage of stream miles, within a range of certainty, that are in good condition.

To pick a random sample, the location of members of the population of interest must be known. The target population for the WSA was the wadeable, perennial streams in the conterminous United States. The WSA design team used the National Hydrography Dataset (NHD)—a comprehensive set of digital spatial data on surface waters—to identify the location of wadeable, perennial streams. They also obtained information about stream order from the River Reach File, a related series of hydrographic databases that provide additional attributes about stream reaches. Using these resources, researchers determined the length of wadeable streams for each of the nine ecoregions (Figure 9).

For this WSA report, the wadeable stream miles assessed for the nation, regions, and ecoregions are referred to as the stream length. The total stream length represented in the WSA for the nation is 671,051 miles. For the Eastern Highlands, Plains and Lowlands, and West regions, the total stream length assessed for the WSA is 276,362 miles, 242,264 miles, and 152,425 miles, respectively.

The 1,392 sites sampled for the WSA were identified using a particular type of random sampling technique called a probability-based sample design, in which every element in the population has a known probability of being selected for sampling. This important feature ensures that the results of the WSA reflect the full range in character and variation among wadeable streams across the United States. Rules for site selection included weighting to provide balance in the number of stream sites from each of the 1st- through 5th-order size classes and controlled spatial distribution to ensure that sample sites were distributed across the United States (Figure 10).

The WSA sites were allocated by EPA Region and WSA ecoregion based on the distribution of 1st- through 5th-order streams within those regions. Within each EPA Region, random sites are more densely distributed where the perennial 1st- through 5th-order streams are more densely located and more sparsely distributed where streams are sparse. For example, EPA Region 4 in the southeastern United States includes large portions of the Southern Appalachian and Coastal Plains ecoregions. The survey design in EPA Region 4 identified more sites in the Southern Appalachians ecoregion, where the stream length is 178,449 miles, than in the Coastal Plains ecoregion, where the stream length is 72,130 miles (see Figure 9).

The basic sampling design drew 50 sampling sites randomly distributed in each of the EPA Regions and WSA ecoregions. Some of the unusually dense site patterns visible on Figure 10 occur because some states opted to increase the intensity of random sampling throughout

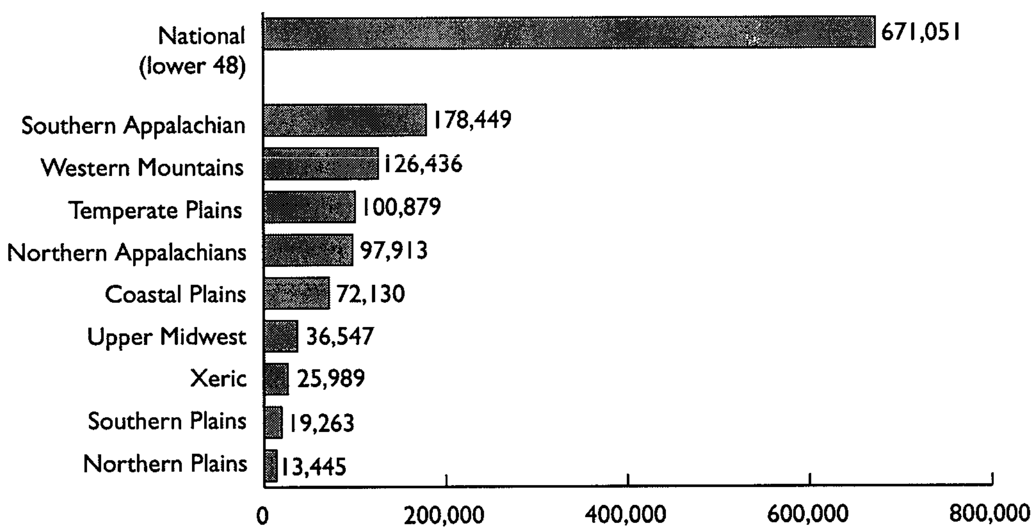


Figure 9. Length of wadeable, perennial streams in each WSA ecoregion (U.S. EPA/WSA).

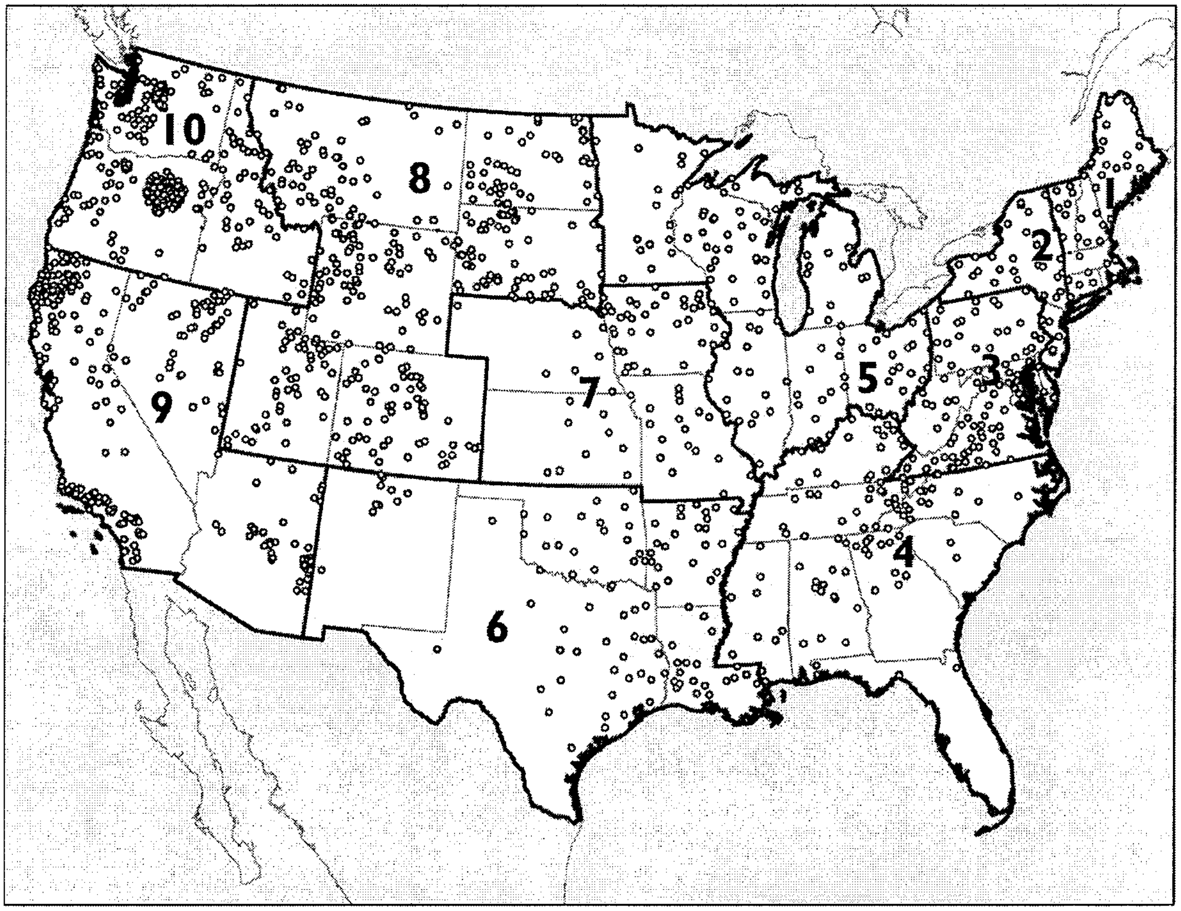
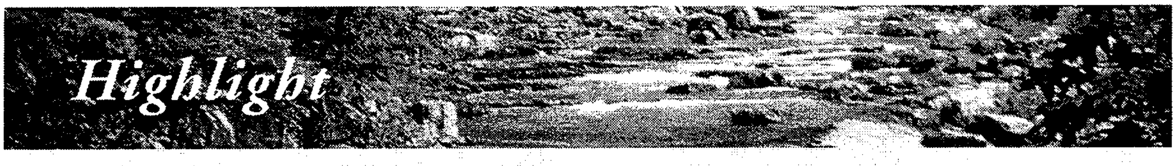


Figure 10. Sites sampled for the WSA by EPA Region (U.S. EPA/WSA).

their state to characterize statewide conditions. Fifteen states, including all states in EPA Regions 8, 9, and 10, increased the number of random sites to 50 sites throughout each state to support state-scale characterizations of stream condition. States also added clusters of random sites to characterize areas of special interest in Washington, Oregon, and California. When sites from an area of intensification were used in the ecoregion assessments, the weights associated with those sites were adjusted so that the additional sites did not dominate the results. The unbiased site selection of the survey design ensures that assessment results represent the condition of the streams throughout the nation.

An additional 150 reserve replacement sites were generated for each of the 10 EPA Regions. These replacement sites were used when site reconnaissance activities documented that one of the original stream sites could not be sampled. For example, sites were replaced when a waterbody did not meet the definition of a wadeable stream (e.g., no flowing water over 50% of the reach) or was unsafe for sampling, or when access to the stream was denied by the landowner.



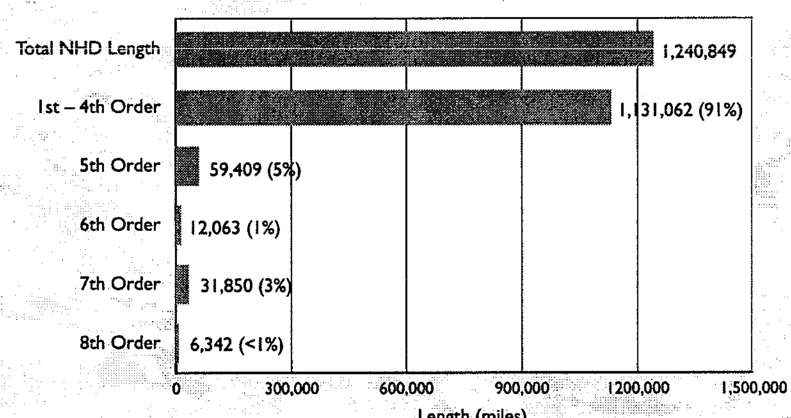
WSA Sampling Frame

The basis of the WSA target population is 1st- through 5th-order perennial streams, which are the streams most likely to be wadeable. The sampling frame used to represent the target population and to select the sites for the WSA is based on the perennial stream network contained in the USGS-EPA NHD. The NHD is a digitized version of 1:100K USGS topographic maps and shows both perennial and non-perennial (e.g., intermittent and ephemeral) streams.

The total stream length in the NHD stream and river network labeled perennial in the conterminous United States is 1,204,859 miles. Of this amount, 1,131,062 miles are 1st- through 4th-order streams, which make up 91% of the total stream length of the nation's flowing waters (see figure below).

Of the more than 1 million miles of stream length labeled as perennial, almost 34% (400,000 miles) were found to be non-perennial or non-target waterbodies (e.g., wetlands, reservoirs, irrigation canals). The remaining target stream length represents the portion of the NHD that meets criteria for inclusion in the WSA (e.g., perennial, wadeable streams). A portion of that target stream length was not sampled for various reasons, including denial of access by a landowner or inaccessibility.

In addition to generating results on the condition of perennial streams, the WSA provides data on the total length of perennial stream miles in the United States. These results will be loaded into the NHD so that the database is updated on the status of perennial/non-perennial stream information.



Estimate of perennial length of streams and rivers from the NHD (U.S. EPA/WSA). The 1st- through 4th-order streams comprise 91% of total estimated stream length in the NHD. The 1st- through 5th-order streams form the basis for the sampling design frame for the WSA.

How Were Waters Assessed?

Each WSA site was sampled by a two- to four-person field crew between 2000 and 2004 during a summer index period. More than 40 trained crews, comprised primarily of state environmental staff, sampled 1,392 stream sites using standardized field protocols. The field protocols were designed to consistently collect data relevant to the biological condition of stream resources and the resources' key stressors.

During each site visit, crews laid out the sample reach and the numerous transects to guide data collection (Figure 11). Field crews sent water samples to a laboratory for basic chemical analysis, whereas biological samples collected from 11 transects along each stream reach were sent to taxonomists for identification of macroinvertebrates. Crews also completed roughly 35 pages of field forms, recording data and information about the physical characteristics

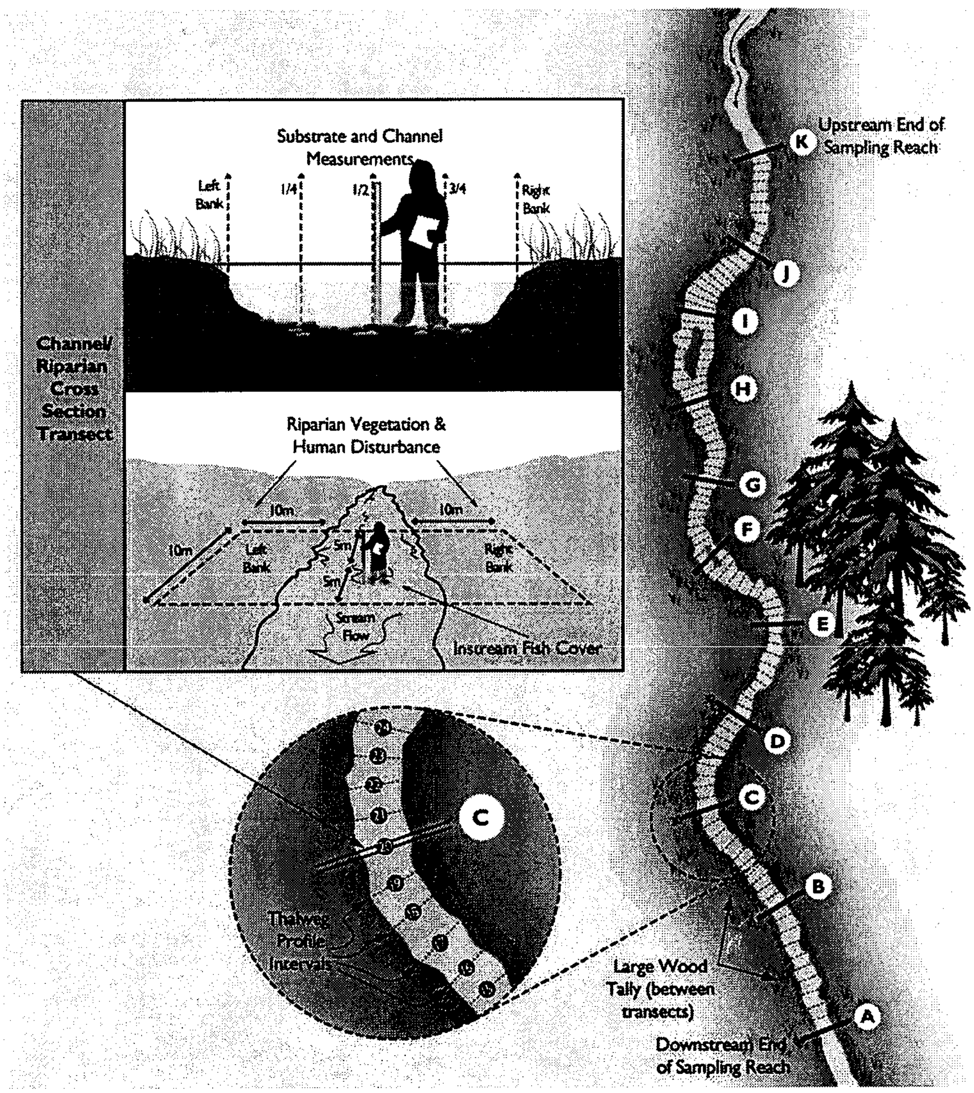


Figure 11. Reach layout for sampling (U.S. EPA/WSA).

of each stream and the riparian area adjacent to its banks. Each crew was audited, and 10% of the sites were revisited as part of the quality assurance plan for the survey.

The use of standardized field and laboratory protocols for sampling is a key feature of the WSA. Because ecologists use a range of methods to sample streams, it is often difficult to compare data collected by different states, regions, or agencies on a regional or national level. Standardization allows the data to be combined to produce a nationally consistent assessment. In addition to collecting a national set of consistent data, this nationwide sampling effort provided an opportunity to examine the comparability of different sample protocols by applying both the WSA method and various state or USGS methods to a subset of the sites. A separate analysis is underway to examine the comparability of these methods and explore options for how the resulting data may be used together.

The WSA uses benthic macroinvertebrates (e.g., aquatic larval stages of insects, crustaceans, worms, mollusks) as the biological indicator of a stream's ecological condition. Benthic macroinvertebrates live throughout the stream bed, attaching to rocks and woody debris and burrowing in sandy stream bottoms and among the debris, roots, and grasses that collect and grow along the water's edge (Figure 12). The

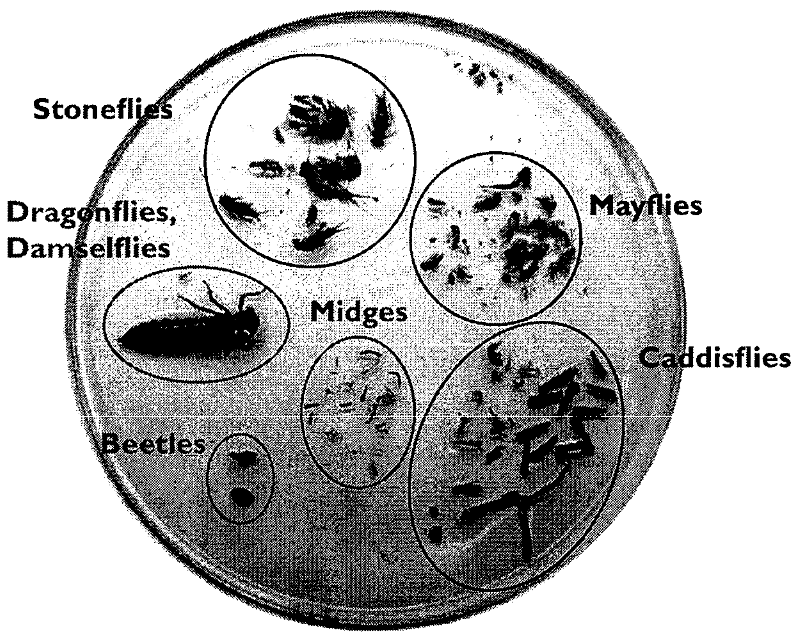


Figure 12. Stream macroinvertebrates (Photo courtesy of Maine Department of Environmental Protection). Macroinvertebrates in streams serve as the basis for the indicators of biological condition for the WSA.

WSA focuses on these macroinvertebrates because of their inherent capacity to integrate the effects of the stressors to which they are exposed, in combination and over time. Stream macroinvertebrates generally cannot move very quickly or very far; therefore, they are affected by, and may recover from, a number of changes in physical conditions (e.g., habitat loss), chemical conditions (e.g., excess nutrients), and biological conditions (e.g., the presence of invasive or non-native species). Some types of macroinvertebrates are affected by these conditions more than others.

Macroinvertebrates provide a measurement of biological condition or health relative to the biological integrity of a stream. Biological integrity represents the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region. Macroinvertebrates are researched by almost every state and federal program that monitors streams and are also increasingly evaluated by volunteer organizations that monitor water quality. In addition, water quality monitoring and management programs are enhancing the understanding of the biological condition of streams by adding other biological assemblages, including fish and algae.

The WSA supplements information on the biological condition of streams with measurements of key stressors that might negatively influence or affect stream condition. Stressors are the chemical, physical, and biological components of the ecosystem that have the potential to degrade stream biology. Some stressors are naturally occurring, whereas others result only from human activities, although most come from both sources.

Most physical stressors are created when we modify the physical habitat of a stream or its watershed, such as through extensive urban or agricultural development, excessive upland or bank erosion, or loss of streamside trees and vegetation. Examples of chemical stressors include toxic compounds (e.g., heavy metals, pesticides), excess nutrients (e.g., nitrogen and phosphorus), or acidity from acidic deposition or mine drainage. Biological stressors are characteristics of the biota that can influence biological integrity, such as the proliferation of non-native or invasive species (either in the streams and rivers, or in the riparian areas adjacent to these waterbodies).

The WSA water chemistry data allow an evaluation of the distribution of nutrients, salinity, and acidification in U.S. streams. The physical habitat data provide information on the prevalence of excess sediments, the quality of in-stream fish habitat, and the quality of riparian habitat alongside streams. Although these are among the key stressors identified by states as affecting water quality, they do not reflect the full range of potential stressors that can impact water quality. Future water quality surveys will include an assessment of additional stressors.

One of the key components of an ecological assessment is a measure of how important (e.g., how common) each stressor is within a region and how severely it affects biological condition. In addition to looking at the extent of streams affected by key stressors, the WSA evaluated the relative risk posed by key stressors to biological condition.

Understanding Biological Condition

The main goal of the WSA is to develop a baseline understanding of the biological condition of our nation's streams. Why is this important?

One of the most meaningful ways to answer basic questions about water quality is to directly observe the communities of plants and animals that live in waterbodies. Aquatic plants and animals—especially the small creatures that are the focus of this study—are constantly exposed to the effects of various stressors; therefore, they reflect not only current conditions, but also the cumulative impacts of stresses and changes in conditions over time.

Benthic macroinvertebrates are widely used to determine biological condition. These organisms can be found in all streams, even in the smallest streams that cannot support fish. Because they are relatively stationary and cannot escape pollution, macroinvertebrate communities integrate the effects of stressors over time (i.e., pollution-tolerant species will survive in degraded conditions, and pollution-intolerant species will die). These communities are also critically important to fish because most game and non-game species require a good supply of benthic macroinvertebrates as food. Biologists have been studying the health and composition of benthic macroinvertebrate communities in streams for decades.

Biological condition is the most comprehensive indicator of waterbody health; when the biology of a stream is healthy, the chemical and physical components of the stream are also typically in good condition. In fact, several states have found that biological data frequently detect stream impairment where chemistry data do not.

Data on biological condition are invaluable for managing the nation's aquatic resources and ecosystems. Water quality managers can use these data to set protection and restoration goals, decide which indicators to monitor and how to interpret monitoring results, identify stresses to the waterbody and decide how they should be controlled, and assess and report on the effectiveness of management actions. In fact, many specific state responsibilities under the CWA—such as determining the extent to which waters support aquatic life uses, evaluating cumulative impacts from polluted runoff, and determining the effectiveness of discharger permit controls—are tied directly to an understanding of biological condition.

Setting Expectations

To interpret the data collected and assess current ecological condition, chemical, physical, and biological measurements must be compared to a benchmark or estimate of what one would expect to find in a natural condition. Setting reasonable expectations for an indicator is one of the greatest challenges to making an assessment of ecological condition. Should we take an historical perspective and try to compare current conditions to an estimate of pre-colonial conditions, pre-industrial conditions, or conditions at some other point in history, or should we accept that some level of anthropogenic disturbance is expected and simply use the best of today's conditions as the benchmark against which everything else is compared?

These questions, and their answers, all relate to the concept of reference condition. What do we use as a reference condition to set the benchmark for assessing the current status of these waterbodies? Because of the difficulty of estimating historical conditions for many of the WSA indicators, the assessment used the conditions at a collection of "least-disturbed" sites as the reference condition. This means that the condition at these sites represents the best available chemical, physical, and biological habitat conditions given the current state of the landscape. Least-disturbed sites were identified by evaluating data collected at sites according to a set of explicit screening levels that define what is least disturbed by human activities. To reflect the natural variability across the American landscape, these levels varied among the nine ecoregions. The WSA compared physical and chemical data collected at each site (e.g., nutrients, riparian condition, chloride, turbidity, fine sediments) to the screening levels to determine whether any given site was in least-disturbed condition for its ecoregion.

A researcher collects macroinvertebrate samples from a small stream in the Northern Appalachians ecoregion (Photo courtesy of the Vermont Department of Environmental Conservation).

Data on land use in the watersheds were not used to screen-out sites. For example, sites in agricultural areas with effective best management practices (BMPs) may have been considered least disturbed, provided they exhibited chemical and physical conditions that were among the best for their region. The WSA also did not use data on biological assemblages as a screening factor to select reference sites because that would have pre-judged expectations for biological condition. Similarly, when selecting least-disturbed reference sites for each stressor, the WSA excluded the specific stressors themselves from the screening process.

The WSA screening process resulted in the identification of a set of least-disturbed reference sites for each WSA ecoregion. These sites were distributed throughout the ecoregions and covered the range of natural variability across each area. Some of these sites included a degree of human-caused variability.

The results from samples collected at the reference sites for the various indicators (e.g., biological condition, nutrients) represent the range of expected values for least-disturbed reference condition. The WSA used this reference distribution as a benchmark for setting thresholds between good, fair, and poor condition. These thresholds were then applied to the random sites to generate the percentage of stream length in each condition class.

The WSA's approach examined the range of values for indicators in all of the reference sites in a region and used the 5th percentile of the reference distribution for that indicator to separate the poor sites from fair sites. Using the 5th percentile means that stream sites and associated stream length in poor condition were worse than 95% of the sites used to define least-disturbed reference condition. Similarly, the 25th percentile of the reference distribution was used to distinguish between sites in fair and good condition. This means that stream length reported as being in good condition was as good as or better than 75% of the sites used to define least-disturbed reference condition.

Within the reference site population, there exist two sources of variability: natural variability and variability due to human activities. Natural variability—the wide range of habitat types naturally found within each ecoregion—creates a spread of reference sites representing these differing habitats. Capturing natural variability in reference sites helps establish reference conditions that represent the range of environments in the ecoregions.

The second source of variation within the reference population is change resulting from human activities. Many areas in the United States have been altered, with natural landscapes transformed by cities, suburban sprawl, agricultural development, and resource extraction. The extent of those disturbances varies across regions. Some of the regions of the country have reference sites in watersheds with little to no evidence of human impact, such as mountain streams or streams in areas with very low population densities. Other regions of the country have few sites that have not been influenced by human activities. The least-disturbed reference sites in these widely influenced watersheds display more variability in quality than those in watersheds with little human disturbance.

Variation within the reference distribution due to disturbance was addressed before benchmarks were set for the condition classes of good, fair, and poor. For regions where the reference sites exhibited a disturbance signal, the data analysis team accounted for this disturbance by shifting the mean of the distribution toward the less-disturbed reference sites.

At a national meeting to discuss data analysis options, WSA collaborators supported this reference condition-based approach, which is consistent with EPA guidance and state practice on the development of biological and nutrient criteria. Additional details on how the least-disturbed condition and benchmarks for the condition categories were established for the WSA can be found in the data analysis method available on the EPA Web site at http://www.epa.gov/owow/streamsurvey.